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GEOPHYSICAL INSTITUTE
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UNIVERSITY OF ALASKA

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INVESTIGATION OF SUNLIT AURORA

Final Report

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Principal Investigator
Gerald J. Romick

Report Approved by:

Co-Principal Investigator
Wallace B. Murcray

Keith B. Mather
Director

INTRODUCTION

The Geophysical Institute of the University of Alaska operated a multi-filter scanning photometer on board the 1969 NASA auroral airborne expedition. The experiment was directed towards the acquisition of two kinds of information. The first concerned studies of the enhancement of the N_2^+ 1NG system through resonant scattering of sunlight. The second concerned the horizontal distribution within discrete auroral forms of the 5577 OI emission relative to that of the N_2^+ 1NG bands under sunlit and midday conditions.

Little data on sunlit aurora were obtained but the observations of midday aurora are of special interest due to the paucity of information available regarding their special characteristics, relative emission height variation and general height range. The data were acquired in combination with another experiment using the same instrumentation on the airborne expedition, funded under NASA grant NGR 02-001-058. This final report summarizes the operation and describes some of the data that were obtained. Additional funding has been requested and used for continuing the data reduction and analysis.

Instrumentation

The proposed experiments required data pertaining to both the spatial distribution and temporal variations of several airglow as well as auroral emission features. The modifications required to use the existing photometer system for these studies were mainly confined to the choice of a suitable detector for the near infrared and the signal detection and processing subsystems. From the outset, there was considerable interest in obtaining and using an S-25 photocathode photomultiplier tube (PMT), which would have adequate sensitivity out to at least 9350 A when moderately cooled, as opposed to a standard S-1(RCA 7102) PMT detector which would have required liquid nitrogen cooling.

An experimental S-25 PMT was ordered from IT&T(F-4075), with sensitivity specifications adequate for the planned observations. Production problems at IT&T left the final decision between the S-1 and the S-25 PMT open until early September 1969 when a low sensitivity S-25 IT&T (F4085) was delivered on consignment for evaluation. A careful laboratory test bench comparison of the S-25 with the S-1 under simulated observational conditions proved that this new tube would be adequate for the proposed observational program. Subsequently it was integrated into the package and the pulse discrimination electronics adjusted accordingly. A second S-25 IT&T PMT, meeting initial specifications, arrived at NASA Ames Research Center Moffett Field, California, just after the checkout flight and was installed, while the F-4085 was retained as a spare. Subsequent operation showed only a little difference in sensitivity between the two tubes; however, in lieu of its slightly higher sensitivity as measured at the factory, it was used throughout the flights and upon completion of the expedition the first tube (F-4085) was returned to IT&T.

From a knowledge of the operational characteristics of the basic optical system when used at shorter wavelengths for other types of auroral and airglow studies, a decision was made to use pulse-counting signal detection techniques. In order to retain flexibility under a variety of possible observational conditions, and also to interface smoothly with the existing analog recording instrumentation, the raw pulse data were converted to analog voltage levels. These were then passed into four separate amplifiers that resulted in four separate decades of signal level which were available simultaneously, ranging from 0 - 200 cps to 0 - 200,000 cps. In operation, pulse pile-up occurred at approximately 40,000 cps. A manual multipole switch placed a load resistor chain across the anode of these same four amplifiers if analog detection were desired over the range of 10^{-7} to 10^{-4} amperes full scale. This feature was used successfully for a short period during a day-to-night transitional flight which occurred during passage from Ft. Churchill to Bodø, Norway.

The remaining modifications were minor, consisting for the most part of installing a 1° resolution shaft encoder assembly on the optical field of view scanning system, reprogramming the filter wheel movement circuitry for positive filter identification and stop-motion movement, and general construction for aircraft mounting. The full specifications of the instrument follow:

The filtered photometer system consisted of a single optical system whose field of view was spatially scanned in elevation angle through a "60° window" of the aircraft and in which narrow band interference filters were programmed to move sequentially into the optical path.

Optics: The objective was an achromat with an entrance aperture of 4.75 inch and focal length of 15.6 inch which was followed by a Ross Corrector-inserted 11.77 inches behind the objective to accommodate 2.8 inch diameter interference filters.

Instantaneous Field of View: 1.19×10^{-4} steradians (0.5° circular)

Effective Spatial Region Viewed: Elevation angle scans were made from a zenith angle of 50° to the zenith perpendicular to the left side of the aircraft.

Field of View-Scanning Rate:

Mode 1 - stationary or manual set point control to within 1° accuracy, with a shaft encoder readout on the operators panel

Mode 2 - motor driven with set point speed control

a. set-point variable, $0^\circ/\text{sec}$ to $450^\circ/\text{sec}$.

b. discrete, 6° ; 12° ; 30° ; 60° ; 150° ; 300° ; $450^\circ/\text{sec}$.

Filter Wheel:

Up to eight separate interference filters were mounted on a programmable wheel with an access plate which permitted changing interference filters during flight conditions if necessary. A discrete eight level electronic code for positive filter identification was displayed on the front panel for the operator and recorded for analysis.

Filter Change Rates:

Mode 1

manual-pushbutton CW or CCW

Mode 2

internal timer which permitted observing time with a given filter of 1, 10 or 25 seconds.

Mode 3

Filter change initiated by pulse derived from elevation scanning optical assembly.

The minimum time between filters was 0.12 sec.

Signal Detection:

Pulse counting followed by digital to analog conversion using a simple R-C integrator. The output of the integrator was fed to four separate amplifiers resulting in four discrete decades of output signal corresponding to:

0 - 2×10^2 cps

0 - 2×10^3 cps

0 - 2×10^4 cps

0 - 2×10^5 cps

with a basic time constant of the integrator of 180 Hz.

Detector:

IT&T F-4075 (S/N 096904) S-25 photocathode,
0.2 inch diameter effective photocathode, 16 dynodes,
operated at 2100 vdc,

Detector Cooler:

Products for Research model TE-102S, operated at set-point of -10°C with stability of 0.1°C .

Recording:

Analog output signals were recorded on seven channels of one of the two available NASA CP 100 Ampex 14 track recorders.

These were:

Channel	Data	Level
1	0 - 2×10^2 cps	-10 to +10 volts
2	0 - 2×10^3 cps	-10 to +10 volts
3	0 - 2×10^4 cps	-10 to +10 volts
4	0 - 2×10^5 cps	-10 to +10 volts
5	Elevation angle position	0 to +10 volts
6	8 level filter identification	0 to +10 volts
7	IRIG B time code	(supplied by NASA)

In addition, a two-channel Sanborn chart recorder was installed in the equipment rack with multipole data access switches, so that the performance of the system could be monitored and checked in flight.

Data Acquisition

The initial ferry flight of the expedition to Ft. Churchill, Canada, occurred on Nov. 24, 1969 and the return ferry flight took place on Dec. 18, 1969.

Table I is a resumé of the data flights carried out between those dates and indicates the mode of operation of the scanning photometer, and the various wavelengths monitored as a function of time during each flight.

During this time interval the magnetic activity was very low and no possibility for detecting sunlit aurora occurred except on flights 12 and 13 associated with the noon crossings of the auroral oval. Flight 12 offers the best opportunity to observe any sunlit effect; however it will take a detailed analysis to determine if any is present. The basic problem is that no particular auroral form was observed when shadow heights were low. However, the high excitation of the OI 6300 emission observed during this flight indicates low energy particle precipitation and an appreciable energy loss at high altitudes (200 to 300 km). As the shadow height was between 160 and 300 km for much of this flight some sunlit effect may appear in the ratios of the various emissions. Discrete arcs were observed poleward of the midday part of the auroral oval and are of particular interest on flight 13; however they were not sunlit.

TABLE I
Operation Resume

1969 Date UT	Flight	Mode of Operation		Time Interval U.T.	Recording Mode		Channel Wavelength							
		Scanning	Zenith		Tape-Chart		1	2	3	4	5	6	7	8
	1	✓	✓	Test Flight		✓								
Nov. 24	2		✓	0806 1231		✓	4278	5893	5577	6300	8630	7250	8345	9350
Nov. 26	3		✓	0042 0133	✓	✓	4278	7250	4861	6772	8911	8630	8345	9350
		✓		0133 0239	✓	✓								
			✓	0239 0307	✓	✓								
		✓		0307 0319	✓	✓								
			✓	0319 0437	✓	✓								
		✓		0437 0611	✓	✓								
Nov. 27	4		✓	0033 0225	✓	✓	4278	7250	6772	8911	8630	8345	9550	4861
		✓		0225 0230	✓	✓								
			✓	0230 0450	✓	✓								
		✓		0450 0532	✓	✓								
Nov. 29	5		✓	0225 0620	✓	✓	4278	7250	6772	8911	8630	8345	9350	4861
Dec. 3	6		✓	0513 0536	✓	✓	4278	7250	6772	8911	8630	8345	9350	4861
		✓		0536 1025		✓								
Dec. 4	7		✓	0450 0930	✓	✓	4278	7250	6772	8911	8630	8345	9350	4861
	8		✓	0610 0640	✓	✓								
Dec. 5		✓		0640 0756	✓	✓								
			✓	0756 0850	✓	✓								
		✓		0850 1000	✓	✓								
			✓	1000 1127	✓	✓								
Dec. 7	9		✓	0515 0600	✓	✓	4278	7250	6772	8911	8630	8345	9350	4861
		✓		0600 0744	✓	✓								
			✓	0744 1016	✓	✓								
Dec. 8	10			0745 1245		✓	4278	7250	6772	8911	8630	8345	9350	4861
Dec. 11	11			1850 2135	✓	✓	4278	7250	6772	8911	8630	8345	9350	4861
		✓		2135 2230	✓	✓								
Dec. 13	12	✓		0630 1130	✓	✓	5577	4278	5000	4861	6300	8911	8345	8630
Dec. 14	13	✓		0530 1030	✓	✓	5577	4278	5000	4861	6300	8911	8345	8630
Dec. 16	14		✓	0120 0203	✓	✓	5577	4278	5000	4861	6300	8911	8345	8630
		✓		0203 0550	✓	✓								
			✓	0550 0553	✓	✓								
		✓		0553 0804	✓	✓								
Dec. 18	15	✓		0817 0933	✓	✓	5577	4278	9350	4861	6300	8911	8345	8630
			✓	0933 1028	✓	✓								
		✓		1028 1426	✓	✓								

Data Reduction

In order to verify the real-time observations of enhanced 6300 OI emission during the two midday auroral oval flights the zenith intensities of various emissions were scaled for flights 12 and 13. These data are plotted in Figs. 1 and 2. Figure 3 illustrates the intensity variation and emission ratio variation across a discrete arc which was observed slightly poleward of the statistical auroral oval on flight 13. Because of the stability of this arc the relative intensity of the various emissions can be determined to study the relative spatial distribution of the 6300 OI, 5577 OI and 4278 N_2^+ emissions.

These preliminary data indicate a high 6300 OI to 5577 OI ratio during most of the flight and especially on the poleward side of the statistical oval. Further analysis will be needed to determine whether or not the discrete arcs have high 6300 OI to 5577 OI ratios, as is present in the general background. Using a composite of the photometric data looking up as in Fig. 3 and other photometric and photographic data looking to starboard of the aircraft we will be able to estimate the relative altitude distributions of the emissions and in turn estimate the actual height of the particular auroral form and any differences which may exist between similar auroral forms seen in the evening or midnight sectors of the auroral oval.

In general the enhanced 6300 OI emission indicates a large number (relatively) of low energy ($< 1 \text{ kev}$) electrons stopped at high altitudes ($> 180 \text{ km}$) where the deactivation of the ^1D state of atomic oxygen through collisions is minimal. A discussion of these preliminary results was presented at the Spring 1970 AGU meeting (Romick, 1970a).

Further analysis of these data have occurred under NASA grant NGR 02-001-048 and discussion of the updated results was presented at the Fall 1970 AGU meeting (Romick, 1970b). The details of that analysis will appear in the final report under that particular grant.

Future program

Under this grant the initial data were obtained and the preliminary studies determined that the data did contain information warranting the need for further funds for the analysis of the data in line with the original concepts of the experiment. Some additional analysis beyond that possible under this grant has been carried out under NASA grant NGR 02-001-048, and additional funds have also been requested. In general we feel that the results of the expedition will be of major benefit to the understanding of the aurora and in acquiring useful information which could not have been obtained as thoroughly any other way. Besides the acquisition of data, another useful and perhaps as scientifically worthwhile an accomplishment of these expeditions is the collaboration and association between investigators which result from the assembly of the various groups from the United States, Canada and Europe in an atmosphere conducive to the exchange of ideas.

REFERENCES

- Romick, G. J. (a), Photometric Measurements Across the Noon Sector of the Auroral Oval, Trans. AGU #3, 1970.
- Romick, G. J. (b), Photometric and Photographic Analysis of Polar Cap Rayed Aurora, Trans. AGU #11, 1970.

LIST OF FIGURES

- Figure 1 Zenith variation of 5577 OI, 6300 OI, 4278 N_2^+ and 4861 H beta emission during Flight 12.
- Figure 2 Zenith variation of 5577 OI, 6300 OI, 4278 N_2^+ and 4861 H beta emission during Flight 13.
- Figure 3 Variation with elevation angle of the intensity and intensity ratio of some of the emissions monitored during the observation of a discrete auroral arc on Flight 13.

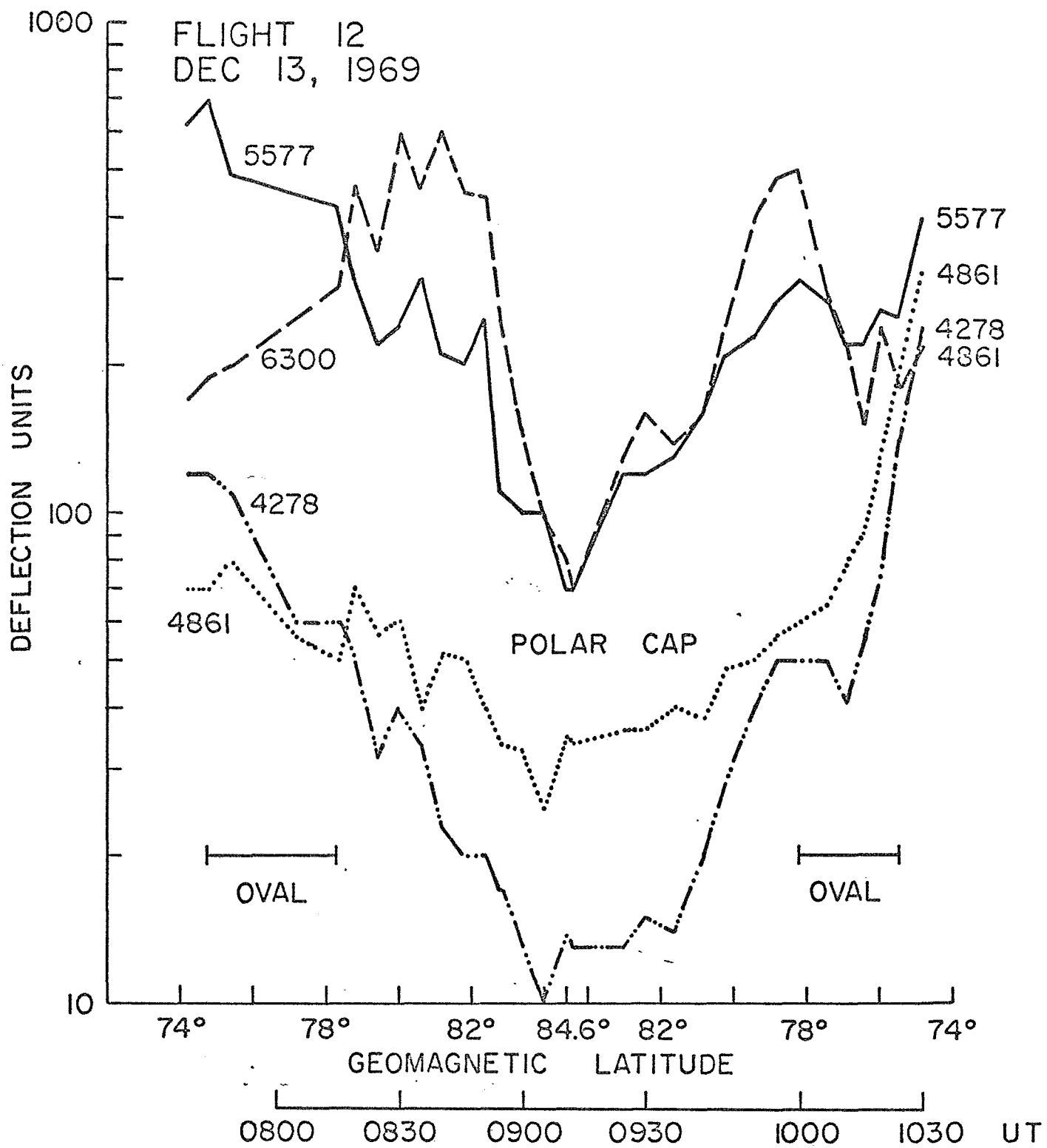


Figure 1

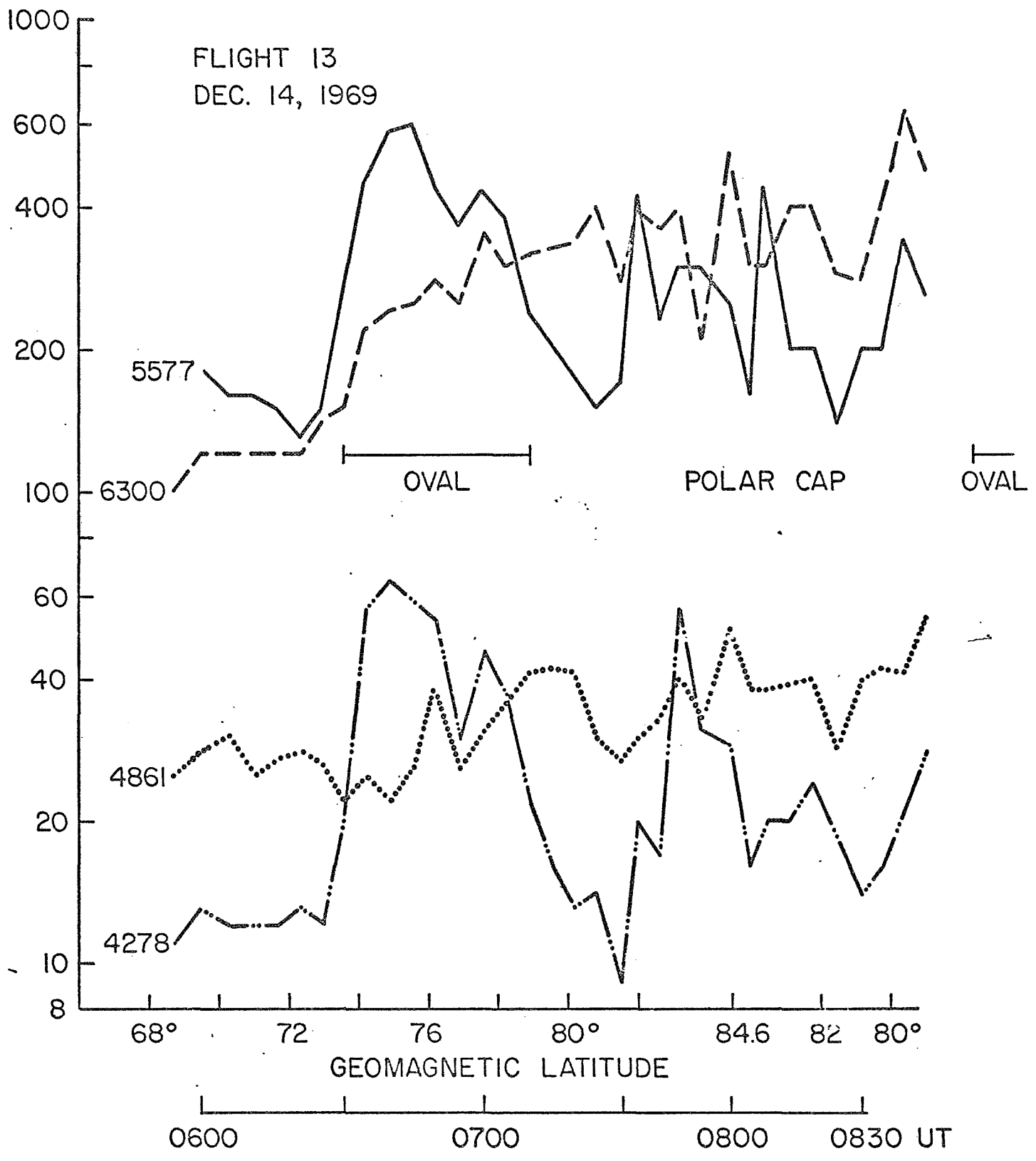


Figure 2

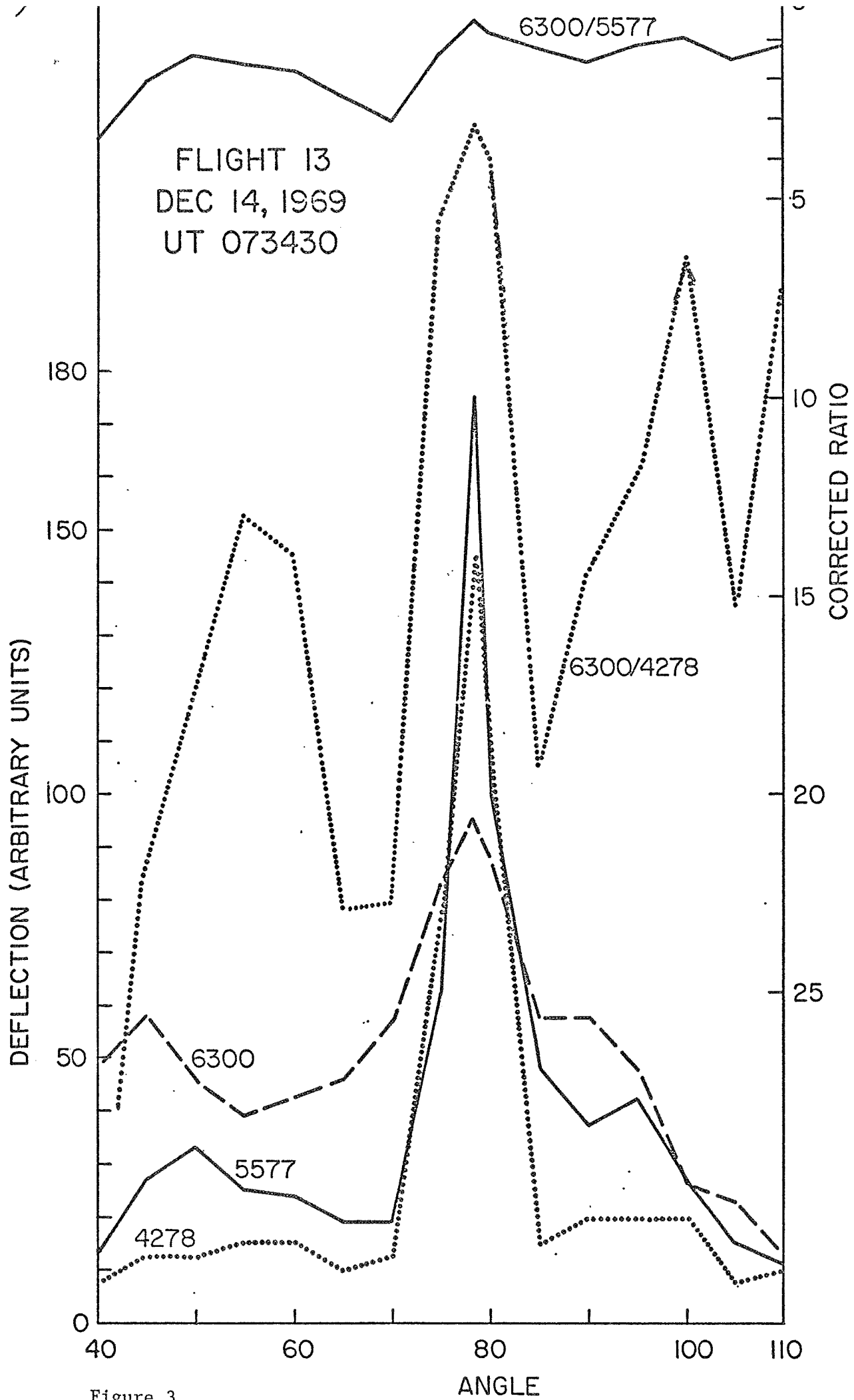


Figure 3